Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

# CONTROL OF THE TOBACCO HORNWORM ON ST. CROIX, U.S. VIRGIN ISLANDS, BY THE STERILE MALE TECHNIQUE

ARS-S-98
February 1976

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

# CONTENTS

Page
Abstract .......... 1
Introduction .......... 1
Procedures .......... 2
  Rearing, sterilizing, marking, and releasing .......... 2
  Field evaluation .......... 3
  Mass trapping .......... 3
Results .......... 3
  Trend of the natural population .......... 3
  Viability of eggs collected .......... 5
  Competitiveness of released males .......... 5
Conclusion .......... 6
Literature cited .......... 6

# ILLUSTRATIONS

Fig.
1. Tobacco hornworm release sites on St. Croix .......... 2
2. Release cage .......... 3
3. Average nightly capture of natural tobacco hornworm moths in unbaited black-light traps before and during releases of sterile males .......... 4
4. Expected and collected nonviable eggs during sterile male releases .... 6

# TABLE

1. Mean rainfall at 12 to 15 weather stations on St. Croix, 1970–72 ....... 5

# ACKNOWLEDGMENTS

We are deeply indebted to the following agricultural research technicians for their important contributions to the program: M. B. Peace, O. Skov, J. Fuertes, B. M. Garcia, C. A. Ascencio, and C. A. Molloy, St. Croix, U.S. Virgin Islands; and J. M. Hobgood, Jr., and C. M. Knott, Oxford, N.C.

# CONTROL OF THE TOBACCO HORNWORM ON ST. CROIX, U.S. VIRGIN ISLANDS, BY THE STERILE MALE TECHNIQUE

By J. Wendell Snow,[1] D. G. Haile,[2] A. H. Baumhover,[3]
W. W. Cantelo,[4] J. L. Goodenough,[5] J. M. Stanley,[6] and T. J. Henneberry[7]

## ABSTRACT

Releases of sterile (irradiated) male tobacco hornworms, *Manduca sexta* (L.), on St. Croix, U.S. Virgin Islands, reduced captures of natural moths in black-light traps during the first quarter of 1972 (when the effects were first evident) by 92.8%, compared with the corresponding period in 1971. In the second quarter, captures were reduced 93.6%, despite the emergence of moths from diapausing pupae produced before the releases began. The percentage of nonviable eggs correlated closely with the percentage of released males in the population, demonstrating that the released males were highly competitive with natural males. These results indicated that continued releases would have completely eliminated the population.

## INTRODUCTION

The concept of controlling insect populations by the introduction of sterile males into the natural population was proposed by Knipling in 1937 (*9*),[8] but the first successful demonstration of such control, the eradication of the screwworm, *Cochliomyia hominivorax* (Coquerel), from Curaçao, did not occur until 1955 (*1*). Other insects similarly eradicated from isolated areas by the technique were the oriental fruit fly, *Dacus dorsalis* Hendel, on Guam (*16*) and the melon fly, *Dacus cucurbitae* Coquillett, on Rota (*15*).

Attempts to apply the method to Lepidoptera have been somewhat less successful. However, Proverbs (*11*) did obtain economic control of codling moths, *Laspeyresia pomonella* (L.), for 3 years by releasing sterilized insects in apple orchards in the Okanagan Valley of British Columbia. At Yakima, Wash., White et al. (*17*) reduced the damage to apples from 50% to 1.57% with sterile insects. Snow et al. (*12*) apparently suppressed the natural population of *Heliothis zea* (Boddie) by sterile male releases on St. Croix, U.S. Virgin Islands, until disease severely reduced the laboratory production and the quality of released males.

Cantelo et al. (*3*) were not able to reduce egg hatch by releasing sterile male tobacco hornworms, *Manduca sexta* (L.), on the island of Vieques, Puerto Rico, despite ratios of sterile to natural males as high as 3.7:1. However, preliminary releases on St. Croix (November 1969 to January

---

[1] Research leader, Screwworm Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Mission, Tex. 78572.

[2] Agricultural engineer, Agricultural Research Service, U.S. Department of Agriculture, Kingshill, St. Croix, U.S. Virgin Islands 00850.

[3] Research leader, Tobacco Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Oxford, N.C. 27565.

[4] Supervisory research entomologist, Plant Genetics and Germplasm Institute, Agricultural Research Center, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md. 20705.

[5] Agricultural engineer, Agricultural Engineering Department, University of Tennessee, Knoxville, Tenn. 37901.

[6] Research leader, Insect Attractants, Behavior, and Basic Biology Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 14565, Gainesville, Fla. 32601.

[7] Area director, Arizona Area, Western Region, Agricultural Research Service, U.S. Department of Agriculture, Phoenix, Ariz. 85040.

[8] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

1970) of moths from pupae irradiated when they were 1 to 2 days old demonstrated improved competitiveness of the sterile males.

Extensive background information about tobacco hornworms on St. Croix is available through mass light-trapping experiments (1966–70) conducted by Cantelo et al. (*6*). The natural population had been reduced by 86% at experiment termination (December 30, 1970). Twenty-five of the light traps were left in operation to monitor the natural population. Thus, we knew that from April through June 1971, just prior to the present study, captures per trap-night (CTN) had averaged 0.915, or 59.1% of the catch in the base year (1966), and that our test was initiated against a viable and reasonably reproductive population.

The experiment reported here was made to determine if sterile males could control the tobacco hornworm population in the isolated situation of St. Croix. St. Croix has a total land area of about 84 square miles and is about 22 miles long and up to 6 miles wide. The nearest landmasses (St. John, U.S. Virgin Islands, and Vieques, Puerto Rico) are about 36 miles away. Complete details concerning island location, rainfall, climate, elevations, vegetation, and light-trap placement were reported by Stanley et al. (*13*).

# PROCEDURES

## Rearing, Sterilizing, Marking, and Releasing

Initially, tobacco hornworms were reared on meridic diet in laboratories at St. Croix (47%) and at Oxford, N.C. (53%). However, production at St. Croix increased so that only 26% were from Oxford in December 1971, 10% in January 1972, and none by mid-March 1972. Both cultures were handled by methods developed principally by A. H. Baumhover (unpublished data) from the basic work of Yamamoto (*18*, *19*). After pupae were collected and sexed, the male pupae were stored on a pad of absorbent paper in open 61- by 47- by 9.5-cm polyethylene trays. Each day, those having dark wing pads (2–3 days from eclosion) were removed, stacked in single layers in 1.4-cm-deep circular plastic trays (to avoid injury from the weight of other pupae), and treated for 30 min with 35 krad of gamma irradiation from a cobalt-60 source. Treatment of pupae within 2 days of emergence is as effective as treatment of adults. This dose reduced the hatch of eggs in the laboratory to an average of 5% (range of 0%–16%). After irradiation, pupae were returned to storage in containers as before, except that the trays were provided with a screen top from which the moths could hang to unfold and harden their wings. Adults were collected daily, sprayed with a 0.1% aqueous solution of Rhodamine B for identification (external marking), placed in small screen cages, and carried to the eight release sites (fig. 1).

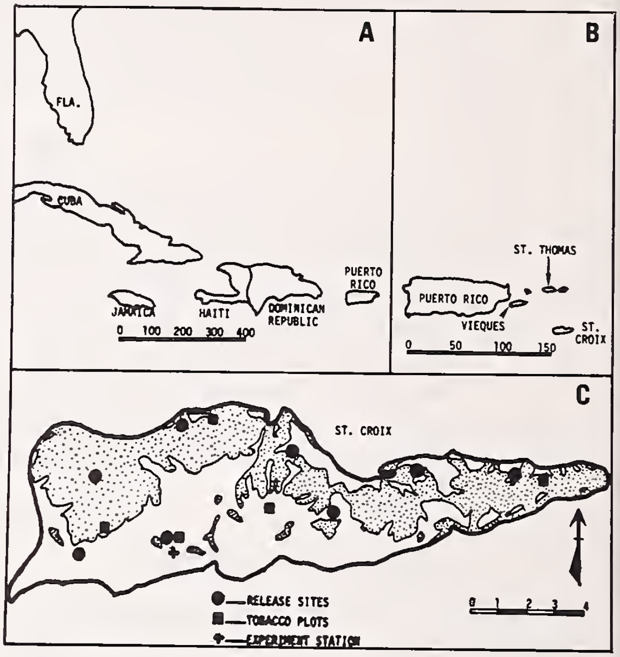

FIGURE 1.—Tobacco hornworm release sights on St. Croix. Eggs were collected in the tobacco plots. Dotted areas indicate a terrain slope of 25% or more. Scale in miles.

The release cages (fig. 2), 4 by 4 by 2 ft, were covered with 1½-inch-mesh fox wire to protect from birds, rats, and other predators. However, adequate protection was achieved only by trapping rodents around the release cages. Shortly after sundown, the males became active and flew from the smaller cage and through the fox wire. Since most birds had become inactive at this time, losses to them were minimal.

For 6 weeks in January and February 1972, Calco Oil Red N–1700 was incorporated into the larval diet at a rate of 4 g/l (*3*) to mark the moths internally, as well as eggs and some spermatophores. As a result, we established that the reared males were definitely mating with natural females because we recovered several natural females with red spermatophores. In addition, we collected 40 marked eggs from tobacco plants, indicating the accidental release of some females. Our subsequent examination of the release cages confirmed that an occasional female was being released because inexperienced personnel were sexing pupae, a problem that was corrected by further training. However, it was perhaps more important that during these 6 weeks, two moths with an internal mark did not have an external mark. Such slight errors in marking and the subsequent misidentification could result in a large error in the ratio of natural to sterile males recorded during periods of low capture of natural males.

### Field Evaluation

Tobacco plots with 25 plants each (fig. 1) were used to evaluate the degree of sterility induced in the population. (Plots were replanted periodically to insure the presence of plants suitable for oviposition.) During the preliminary phase of the program (July 26–September 26, 1971), a single plot was maintained at the experiment station; however, by October 4, 1971, when sufficient males were being released to affect sterility, the number of plots was increased to four. On October 18, 1971, it was increased to five for the remainder of the test. All plots, except that at the experiment station, were at least 1 mile from a release site. (Other known hosts—tomato, sweetpotatoes, and turkeyberry, *Solanum torvum* Sw. Prodr.—were sampled periodically but yielded too few eggs for evaluation.) Initially, one count was made in each plot each week, but the number of counts was increased to five per week by January 3, 1972, because the declining natural population was producing so few eggs.

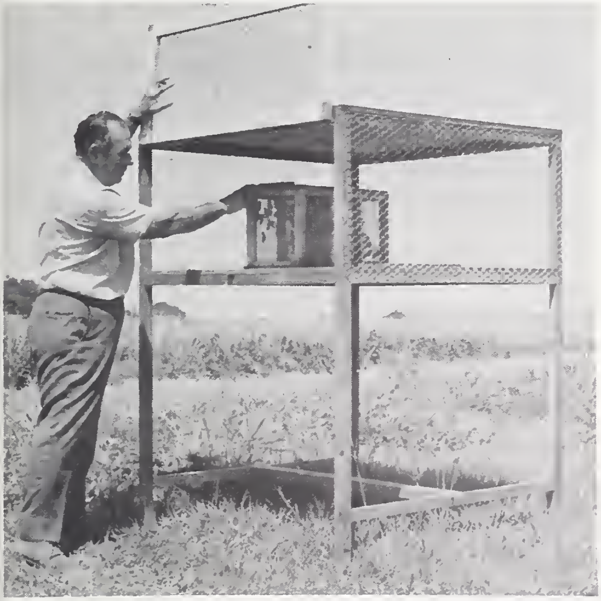

FIGURE 2.—Release cage. Large cage protected moths from predators. Small cage was used to transport moths to release sites.

An index of the populations of natural and sterile moths was obtained by continuous operation of the 25 black-light traps used by Cantelo et al. (*4*) to monitor the buildup of the hornworm population after termination of mass trapping. In early December 1971, 25 additional traps, each baited with 10 virgin female hornworm moths, were operated on the island in other tests. These baited traps increased the male catch tenfold compared with unbaited traps, as reported by Hoffman et al. (*8*) and Cantelo and Smith (*15*). Therefore, they were maintained throughout the remainder of our tests because the capture of natural males in the unbaited traps was by this time too low to adequately assess the ratio of released to natural insects.

### Mass Trapping

On July 1, 1971, 2 weeks before the first sterile male releases, the entire light-trap system of 250 traps (*13*) was placed back in operation to aid in reducing the natural population. This procedure was consistent with the principle of integrating other controls with sterile releases to bring the population within manageable levels (*10*). However, after November 1, 1971, when the releases of males were obviously adequate, these traps received no maintenance.

## RESULTS

### Trend of the Natural Population

The emergence patterns of tobacco hornworm moths on St. Croix vary greatly during the year, partly because some of each generation diapause (Cantelo, unpublished data), though the proportions are not known. Also the amount of rainfall influences the rate of emergence of moths from pupae. Other unknown factors may also be involved. Thus, the full impact of suppressive measures during a period corresponding to one normal generation may not be produced until several months have elapsed. Since the variables cannot be assessed quantitatively, the best evaluation of the influence of sterile male releases on the population is obtained by comparing the relative size of the population at comparable periods before and after releases were made. The operation of the black-light traps may have contributed significantly to the suppression, but the released males were largely responsible based on the sterility of eggs deposited by the natural females.

Figure 3 shows the trend of the natural population from July 1970 through June 1972 based on the catches in unbaited traps. The number of sterile males released beginning July 1971 and terminating in May 1972 is also shown. During the third quarter (July, August, and September) of 1971 when the releases were too low to produce any significant reduction (hatch did drop as low as 63.0% during the third week in September, but suppression would not be evident until a full life cycle), the CTN averaged only 0.282, compared with 0.629 during the equivalent period in 1970. This difference may have occurred largely because of the effect of the low rainfall (table 1) during July 1971 (only 0.98 inch compared with 4.05 inch during 1970), or the decrease may have resulted in part from the light traps that were in operation.

The CTN during the fourth quarter of 1971 was 0.211, compared with 0.685 in 1970, a reduction of 69.2%. Again, trapping could account for some part of the reduction, and rainfall was low, 2.49 and 3.63 inches, respectively, in November and December 1971, compared with 6.40 and 10.89 in 1970. However, the dramatic drop in populations during early December can probably be attributed largely to the effect of sterility on egg viability.

During the first quarter of 1972, when the effects of the releases on populations were strongly evident, captures of natural moths in the black-light traps were 92.8% below the corresponding period in 1971 despite adult emergence from diapausing pupae that began in March. Also, egg viability was low or nonexistent during this period; indeed, eggs were difficult to collect. Only 42 were found (none hatched) in 9 weeks. Meanwhile, the net effect of light trapping appears to have been minimal. The main contribution of these traps was the capture of natural females to December 6, 1971, but only an occasional female was captured thereafter until diapausing moths began to appear the last week in March. In the second quarter, the CTN averaged 0.058, compared with 0.915 during 1971, a reduction of 93.6%, despite the continued emergence of natural insects from diapause. Rainfall during this quarter was less favorable to the natural population

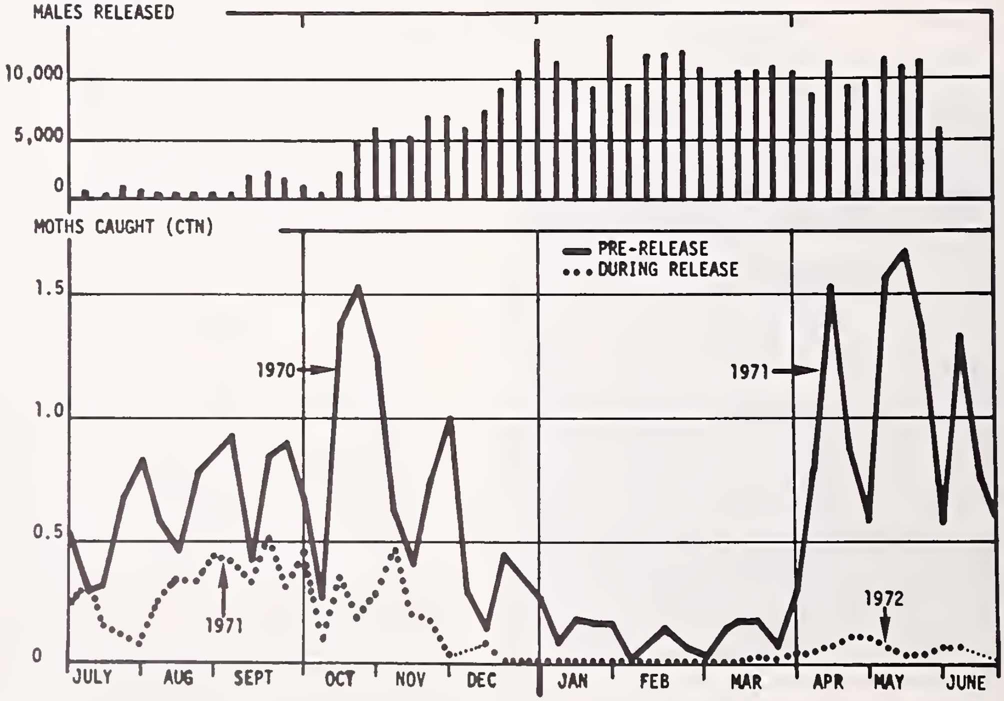

FIGURE 3.—Average nightly capture of natural tobacco hornworm moths (males and females) in unbaited black-light traps (lower graph) before and during releases of sterile males (upper graph).

TABLE 1.—*Mean rainfall (inches) at 12 to 15 weather stations on St. Croix, 1970–72*

| Month | 1970 | 1971 | 1972 |
|---|---|---|---|
| January | 1.02 | 1.92 | 2.94 |
| February | .77 | 2.82 | 2.26 |
| March | .41 | 1.39 | 4.01 |
| April | 1.80 | 3.97 | 1.85 |
| May | 5.64 | 3.90 | 1.11 |
| June | 5.84 | 1.15 | 2.33 |
| July | 4.05 | .98 | ... |
| August | 3.54 | 5.66 | ... |
| September | 4.99 | 4.34 | ... |
| October | 7.30 | 7.07 | ... |
| November | 6.40 | 2.49 | ... |
| December | 10.89 | 3.63 | ... |

Source: Climatological Data, Puerto Rico and Virgin Islands, U.S. Department of Commerce.

than in 1971 since it ranged from 1.11 to 2.33 inches, compared with 1.15 to 3.97 inches in 1971.

The rapidity with which the effect of the releases became evident is notable. During the earlier mass-trapping program on St. Croix, the lowest CTN, 0.088, occurred during the first quarter of 1968, 31 months after trapping began. During this test, the CTN reached 0.0084 after only 5 months (November 1971–March 1972) of effective releases (90.5% less than in the same quarter in 1968). The sterile male releases in the present test therefore had a much stronger suppressive effect than the mass trapping of earlier tests.

Ratios of sterile to natural males from the first release (July 5) through late October 1971 ranged from 0 to 0.56 because so few males were released. In the next 4 weeks, as the weekly release totals were increased (4,313–5,814), the released males recaptured began to outnumber natural males. Thereafter, the ratio of released to natural males increased steadily and reached a high of 160 sterile to 1 natural male during the third week in March 1972. A favorable ratio of sterile males was maintained until the third week in April 1972, when the emergence of moths from diapausing pupae caused a considerable decline.

## Viability of Eggs Collected

Enough eggs were collected to provide reliable data on viability except for 7 weeks in January, February, and March of 1972. Figure 4 shows effects of sterile male releases on the percentage of nonviable eggs collected. The expected egg hatch calculated on the basis of 95% hatched eggs from fertile-mated and 5% hatch from sterile-mated females is also shown (*7*). The close fit of these lines, even during periods of low releases, indicates that the laboratory males were competitive. Therefore, egg hatch was predictable from the ratio of released to natural males and vice versa. This is probably the most significant finding of the entire study.

## Competitiveness of Released Males

As noted, figure 4 shows that the released males were highly competitive with natural males for natural females. Competitiveness for two periods was calculated by averaging the weekly observed hatch and expected egg hatch. This procedure automatically incorporated hatch adjustments (95% hatch for natural × natural and 5% hatch for sterile × natural) and gave equal weight to weekly periods (trap captures and eggs collected varied considerably among weeks).

The first calculation was made for an 8-week period (November 2–December 21) after the beginning of effective releases. The ratio during the period varied from 1:1 to 1:10, and collections of eggs were high enough to give valid results. During this period, the average weekly observed hatch was 28.0%, and the average expected hatch was 29.8%. Released males were therefore 106% competitive with natural males.

The next several months did not provide data for such an assessment because the captures of natural males and the number of eggs collected were low. However, the final 10 weeks of full releases (May 27–June 4) provided another opportunity for the calculation because the emergence of moths from diapausing pupae caused larger numbers of eggs to be oviposited on the tobacco. During this period the average observed and expected egg hatches were 28.4% and 25.5%, respectively. Thus, the competitiveness of released males was calculated as 90%.

For the entire study, the performance of released males reached or approached full competitiveness with natural males, and egg hatch was predictable from the observed ratio of sterile to natural males. A possible significant factor in this result may be the essentially monogamous nature of hornworm females. Thus, sperm competitiveness would not be a factor. Indeed, before the releases, only 6.8% of the native females collected from black-light traps had mated more than once, and this percentage did not change with the releases. Also, controlled experiments had shown that hornworm females that had mated with sterile males were no longer attractive to other males.

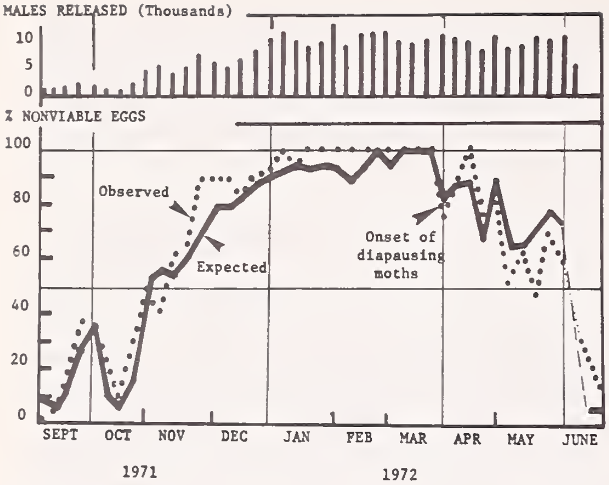

FIGURE 4.—Expected and collected nonviable eggs (lower graph) during sterile male releases (upper graph).

## CONCLUSION

Releases of sterile male hornworms on St. Croix were discontinued in early June 1972 when the total population of moths had been reduced more than 90%. However, it might have taken months or even a year or longer to eliminate the population because of the diapause behavior of the tobacco hornworm on St. Croix. The program did demonstrate that a highly competitive male was capable of suppressing a natural population. The overall result is an effective, nonchemical method of controlling the tobacco hornworm.

## LITERATURE CITED

(1) Baumhover, A. H. 1966. Eradication of the screwworm fly. J. Am. Med. Assoc. 196: 240–248.

(2) Cantelo, W. W. 1973. Dye markers for moths of the tobacco hornworm. Environ. Entomol. 2: 393–396.

(3) ———, Baumhover, A. H., Henneberry, T. J., and Smith, J. S., Jr. 1973. An attempted suppression of the tobacco hornworm by the sterile male technique. Environ. Entomol. 2: 48–54.

(4) ———, Goodenough, J. L., Baumhover, A. H., Stanley, J. M., and Henneberry, T. J. 1973. Mass trapping with blacklight: Effects on isolated populations of insects. Environ. Entomol. 3: 389–395.

(5) ———, and Smith, J. S., Jr. 1971. Attraction of tobacco hornworm moths to blacklight traps baited with virgin females. J. Econ. Entomol. 64: 1511–1514.

(6) ———, Smith, J. S., Jr., Baumhover, A. H., Stanley, J. M. and Henneberry, T. J. 1975. Suppression of an isolated population of the tobacco hornworm with blacklight traps unbaited and baited with virgin female moths. Environ. Entomol. 1: 253–258.

(7) Fried, M. 1971. Determination of sterile-insect competitiveness. J. Econ. Entomol. 64: 869–872.

(8) Hoffman, J. D., Lawson, F. R., and Peace, B. 1966. Attraction of blacklight traps baited with virgin female tobacco hornworm moths. J. Econ. Entomol. 59: 809–811.

(9) Knipling, E. F. 1959. Screwworm eradication: Concepts and research leading to the sterile-male method. *In* Smithsonian Report for 1958, Publication 4365, pp. 409–418.

(10) ———. 1972. Use of organisms to control insect pests. J. Environ. Qual. 1: 34–40.

(11) Proverbs, M. D. 1970. Orchard assessment of radiation sterilized moths for control of *Laspeyresia pomonella* (L.) in British Columbia. Proc. FAO/IAEA Panel Application of Induced Sterility for Control of Lepidopterous Population, Vienna, Austria, pp. 117–133.

(12) Snow, J. W., Burton, R. L., Sparks, A. N., and Cantelo, W. W. 1971. Attempted eradication of the corn earworm from St. Croix, U.S. Virgin Islands. U.S. Dep. Agric. Prod. Res. Rep. No. 125, 12 pp.

(13) Stanley, J. M., Baumhover, A. H., Cantelo, W. W., Smith, J. S., Jr., Peace, M. B., and Asencio, C. A. 1971. A population suppression experiment for tobacco hornworms and other nocturnal insects using blacklight traps on an isolated island, preliminary studies. U.S. Dep. Agric., Agric. Res. Serv. [Rep.] ARS-42-193.

(14) ———, Lawson, F. R., and Gentry, C. R. 1964. Area control of tobacco insects with blacklight radiation. Trans. Am. Soc. Agric. Eng. 7: 125–127.

(15) Steiner, L. F., Harris, E. J., Mitchell, W. C., Fujimoto, M. S., and Christenson, L. D. 1965. Melon fly eradication by overflooding with sterile flies. J. Econ. Entomol. 58: 519–522.

(16) ———, Hart, W. G., Harris, E. J., Cunningham, R. T., Ohinata, K., and Kamakahi, D. C. 1970. Eradication of the oriental fruit fly from the Marina Islands by the method of male annihilation and sterile insect release. J. Econ. Entomol. 63: 131–135.

(17) White, L. D., Hutt, R. B., and Butt, B. A. 1969. Releases of unsexed gamma-irradiated codling moths for population suppression. J. Econ. Entomol. 62: 795–798.

(18) Yamamoto, R. T. 1968. Mass rearing of the tobacco hornworm. I. Egg production. J. Econ. Entomol. 62: 170–174.

(19) ———. 1969. Mass rearing of the tobacco hornworm. II. Larval rearing and pupation. J. Econ. Entomol. 62: 1427–1431.

TRADE NAMES ARE USED IN THIS PUBLICATION SOLELY FOR THE PURPOSE OF PROVIDING SPECIFIC INFORMATION. MENTION OF A TRADE NAME DOES NOT CONSTITUTE A GUARANTEE OR WARRANTY OF THE PRODUCT BY THE U.S. DEPARTMENT OF AGRICULTURE OR AN ENDORSEMENT BY THE DEPARTMENT OVER OTHER PRODUCTS NOT MENTIONED.

*1976-G.P.O.-1750-S-671-583/31

b